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A STATISTICAL STUDY OF SURFACE AND UPPER-AIR CONDITIONS IN CYCLONES AND ANTICYCLONES PASSING OVER DAVENPORT, IOWA.[1]

By ANTON D. UDDEN.

[University of Pennsylvania, Philadelphia, Pa., October 23, 1922.]

SUBJECT AND PURPOSE OF INVESTIGATION.

This paper presents the results of a statistical study of surface and upper-air conditions in cyclones and anticyclones passing over Davenport, Iowa. A knowledge of such conditions is essential in the forecasting of weather. It is also a matter of importance to aerial navigation. The surface-air conditions can readily be studied by means of the daily weather maps and the station data of the United States Weather Bureau. It is more difficult, however, to obtain information on the upper air. This is usually accomplished by sending up kites and balloons equipped with specially designed apparatus for recording the upper-air conditions, and by following the progress of a pilot balloon with a theodolite. The cloud records made at the United States Weather Bureau stations also constitute a valuable source of information. The upper-air studies described in this paper, are based upon such cloud data. In preparing this paper the writer has wished to direct attention to a statistical method which appears useful in the study of local weather conditions in the distribution of the weather elements of HIGHS and LOWS and also to call to notice the great wealth of material for investigation which has accumulated in the stations of the United States Weather Bureau.

METHOD OF STUDY.

The statistical method which has been employed in this investigation is similar to the one previously used by Clayton in his cloud studies. The mechanical details of the method, however, were taken from a paper by J. A. Udden. A diagram is constructed, as shown in Figure 1, for the purpose of dividing a cyclone or anticyclone into a number of definitely circumscribed areas. Four concentric circles are drawn, whose radii represent distances of 100, 400, 700, and 1,000 miles, respectively. Eight radii 45° apart and extending from the inner to the outer circle, delimit 24 subareas symmetrically oriented about the central one. These are numbered consecutively from 1 to 25, as shown in the figure.

The diagram just described is here used to subdivide a cyclone or anticyclone into small areas in order to study the average weather conditions prevailing in each area when it overlies Davenport, Iowa. It is drawn to the scale of the United States daily weather maps upon a sheet of transparent paper. Having selected a weather map in which Davenport is situated within a HIGH or LOW, the next step is to determine the region of the cyclone or anticyclone in which the city lies. The center of the diagram on the transparent paper is then superposed upon the center of the LOW or HIGH in such a manner that the north-south diameter of the diagram coincides with the meridian. The number of the subarea in which Davenport lies can then be read off directly. Thus, in Figure 2, which illustrates the procedure, Davenport falls within subarea 15 of the cyclonic diagram. In this case the city lies within that part of a LOW whose center overlies the eastern part of the Province of Ontario, Canada.

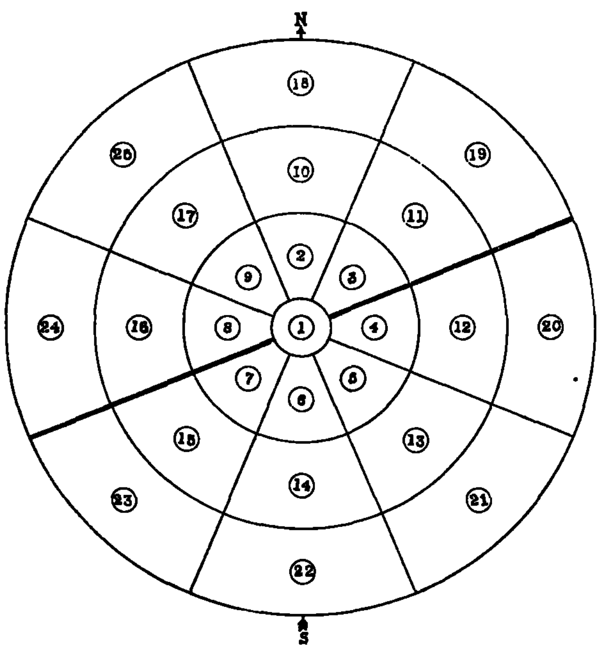

FIG. 1.—Arrangement of 25 subareas in a diagram used for finding the location of Davenport in different parts of cyclones and anticyclones as shown on the daily maps of the U. S. Weather Bureau.

It is now a simple matter to note the weather conditions prevailing in subarea 15 of the cyclonic diagram. Upon examining a large number of weather maps, Davenport is found frequently to appear in this area. By obtaining a sufficient number of observations, it is possible to calculate the average weather conditions, such as the amount of cloudiness, wind velocity, frequency of precipitation, etc., characteristic of any particular subarea of a LOW when that subarea overlies Davenport. Similarly, we may obtain the average weather conditions which Davenport experiences in each one of the 25 subareas of cyclones (or anticyclones) represented on the diagram.

SOURCE AND CHARACTER OF DATA.

The present investigation is based upon an examination of the morning and evening weather maps for a period of 22 years, from 1892 to 1913, inclusive. Approximately 13,000 maps were examined. The files of

[1] This manuscript has been received since the untimely death of the author on Sept. 5, 1922, at San Antonio, Tex. Cf. MO. WEATHER REV., October, 1922, 50: 540.

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the Davenport Weather Bureau station supplied the morning maps, and the evening maps were studied at the Chicago Weather Bureau office. All of the observational data were obtained from the Davenport station.

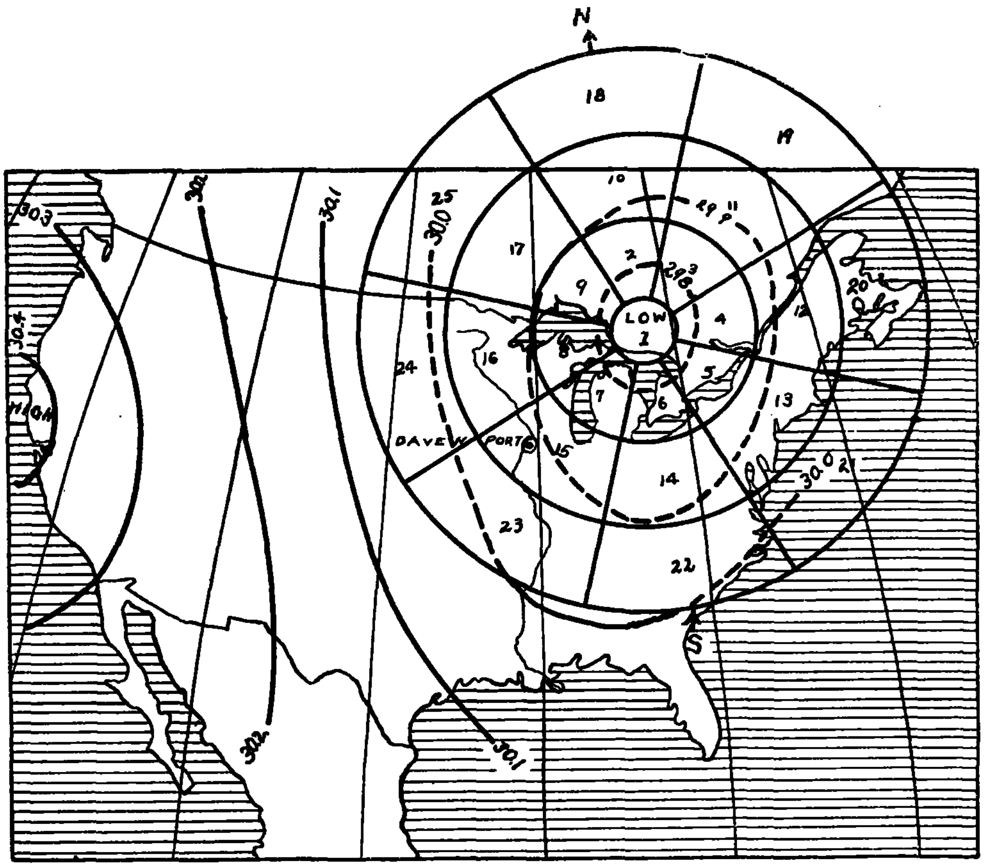

Fig. 2.—Diagram superimposed on the center of a LOW on the United States weather map, to locate the area in which Davenport falls.

LOCATION AND TOPOGRAPHY OF DAVENPORT, IOWA.

Davenport is situated in the upper Mississippi Valley at latitude 41° 30′ and longitude 90° 30′ west of Greenwich. The city is about 606 feet above sea level. It is surrounded on all sides by comparatively level land almost all of which is under cultivation. The Great Lakes to the northeast constitute the nearest large body of water. Numerous small lakes are also found in Wisconsin and Minnesota on the north. This large water surface probably exerts a noticeable effect upon the weather conditions at Davenport.

Davenport lies on the west bank of the Mississippi River, whose valley extends several miles eastward of the city. In the opposite direction the valley broadens out and turns to the southwest. The Weather Bureau station is situated about 1,500 feet from the bank of the river and approximately 75 feet below the level of the upland. Roughly speaking, the station lies about halfway up the slope from the river's edge.

SURFACE AND UPPER AIR CONDITIONS IN THE SUBAREAS OF CYCLONES OVERLYING DAVENPORT, IOWA.

Number of observations.—The number of times that Davenport was within each subarea of the cyclonic diagram is shown in Figure 3. The numbers include both morning and evening observations for the entire period under consideration. Thus the city was visited by the central area of cyclones 119 times, while in subarea 15 there were 521 observations. The distribution of the number of observations among the various subareas of the cyclonic diagram is shown graphically by the shaded areas. The more darkly stippled regions represent increasingly larger numbers of observations. The limiting values of each degree of shading may be ascertained from the numbers within the small rectangles along the boundary lines of the shaded areas. In Figures 3 and 4, there are six degrees of shading whose limiting values are given in the following table:

	Number of observations.
1. Unshaded	0–100
2. Light stipple	101–200
3. Medium stipple	201–300
4. Dark stipple	301–400
5. Very dark stipple	401–500
6. Solid black	501–600

A like interpretation applies to all similar diagrams in this paper.

The number of times that Davenport was visited by each cyclonic area is of importance in determining the reliability of the average values of the weather elements for the various subareas. Davenport appeared most frequently in subarea 15 of the cyclonic diagram, in all 521 times. The smallest number of observations, namely 17, is found in subarea 18. With such extremes, it is evident that the averages in some subareas will be more reliable than in others. It is believed, however, that the average values of the weather elements will be fairly reliable except in 18 and 25. The total number of observations in the cyclones is 4,318.

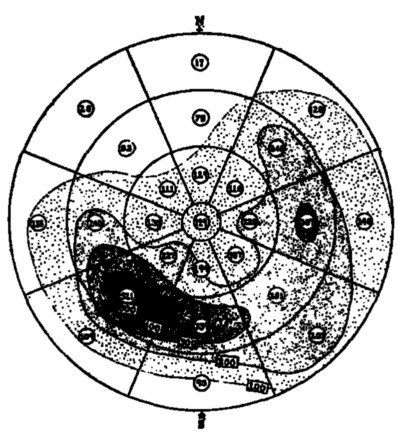

Fig. 3.—Number of observations in the different subareas of cyclones at Davenport.

Frequency of observations in different subareas.—The total number of observations in any one of the subareas of a cyclone depends upon two factors. First, the number is proportional to the frequency with which cyclones travel along those paths which include Davenport within the given subarea. Secondly, the number of observations is proportional to the areas of the several subdivisions of the Figure 1. By expressing the number of observations in each part in terms of the same unit of

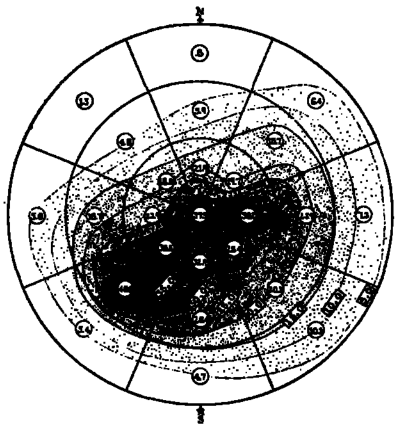

FIG. 4.—Frequency of observations in percentages for the separate subareas of cyclones at Davenport.

area, we obtain the frequency with which Davenport falls within any particular part of a cyclone. The

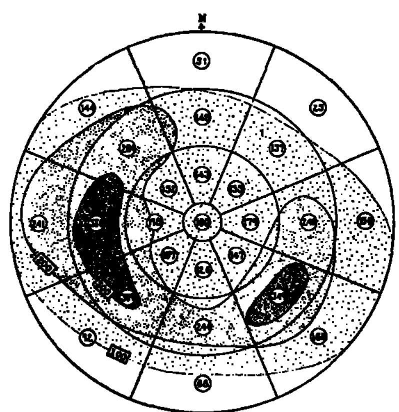

FIG. 5.—Number of observations in the different subareas of anticyclones at Davenport.

frequency values given in Figure 4 represent the number of observations per 10,000 square miles of area.

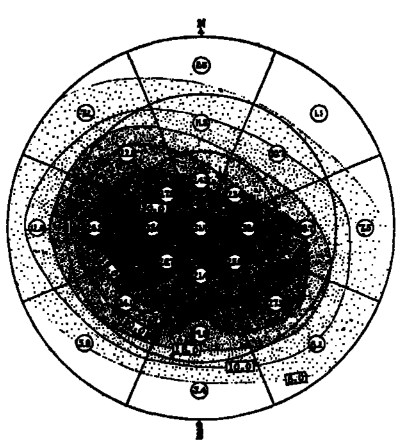

FIG. 6.—Frequency of observations in percentages for the separate subareas of anticyclones at Davenport.

It is interesting to note that the frequency areas in cyclones (see fig. 4) are elongated from WSW. to ENE. This agrees approximately with the direction of the storm tracks across Davenport as shown by Van Cleef. Furthermore, the frequency values below the WSW.–ENE. diameter [3] are considerably greater than those found in the corresponding upper subareas. This is clearly shown in the table given below, in which the last column expresses in per cent the ratio of the frequencies in the lower (southern) to those in the corresponding upper (northern) subareas. From this we may conclude that the cyclone centers travel more frequently to the north of Davenport than to the south.

TABLE 1.—*Frequencies of observations in upper (northern) and lower (southern) subareas (see fig. 4).*

Lower.	Subarea number.	Upper.	Subarea number.	Ratio, lower to upper.
				Per cent.
7.3	20	6.4	19	114
23.9	12	18.7	11	128
38.2	4	19.7	3	194
10.2	21	.8	18	1,275
20.3	13	5.9	10	344
28.4	5	21.9	2	130
4.7	22	1.3	25	362
26.4	14	4.8	17	550
32.9	6	18.8	9	170
5.4	23	5.6	24	96
40.6	15	18.7	16	217
38.5	7	22.9	8	168

DIRECTION OF THE SURFACE WINDS AND THE CURRENTS IN THE UPPER AIR IN CYCLONES.

Surface winds.—Davenport experiences a characteristic resultant surface wind direction in each of the 25 areas of the cyclonic diagram. Similarly, each type of clouds possesses a resultant direction in every subarea. This resultant may be obtained vectorially. For example, Davenport was visited by the central area of cyclones 119 times, during which the surface wind blew as follows:

Direction from which wind blew.	Number of times.
N	7
NE	9
E	17
SE	15
S	21
SW	29
W	14
NW	7
Total	119

The vector diagram of these wind directions is plotted in Figure 7.

Beginning at "A" each of the directions is represented, consecutively, with a line whose length and direction indicate the number of times that the wind blew from the given direction. The resultant directon is given by the heavy line AB, which closes the polygon.

The resultant wind and cloud directions within each of the subareas of the cyclonic diagram have been studied at five arbitrary levels, namely:

Levels.	Altitude in feet (approximate average.)
Surface wind	
Nimbus and stratus clouds	2,300
Cumulus, strato-cumulus and cumulo-nimbus clouds	6,000
Alto-stratus and alto-cumulus clouds	13,000
Cirrus cirro-stratus and cirro-cumulus clouds	23,000

The direction of the wind at the higher altitudes was obtained from the observed motion of the clouds within the respective subareas. In each of the diagrams,

[3] The heavy line in figure 1 divides the subareas into upper and lower group.—ED.

Figures 8, 9, 12, 13, and 16, the resultant directions are represented by arrows flying with the wind. The

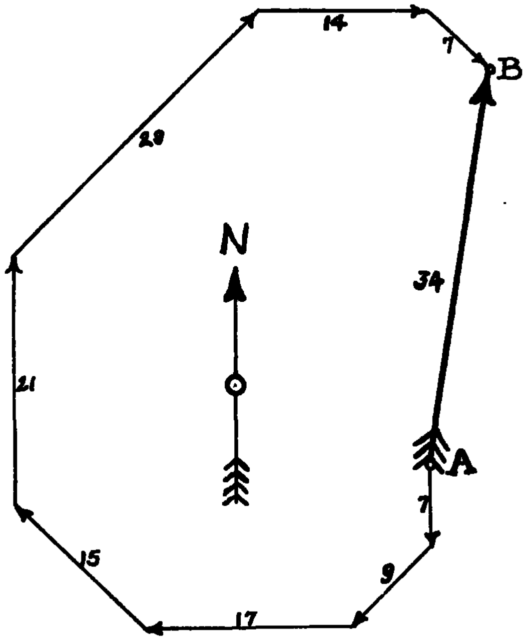

FIG. 7.—Vector diagram showing resultant surface wind direction in the central subarea of cyclones at Davenport.

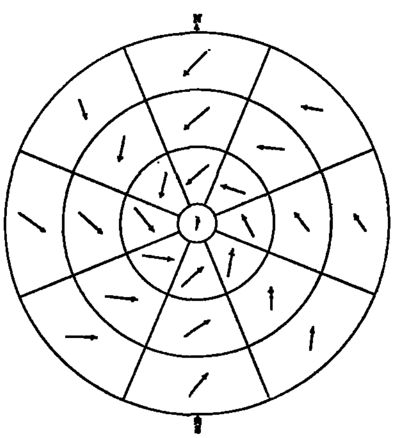

FIG. 8.—Direction of surface winds in cyclones at Davenport.

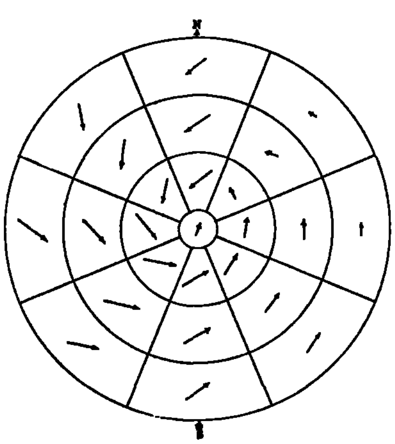

FIG. 9.—Direction of motion of nimbus and stratus clouds in cyclones at Davenport.

length of the arrow indicates the constancy with which the wind blows in the given direction. The broken arrows indicate that the directions in the subarea where such arrows occur are based upon five observations or

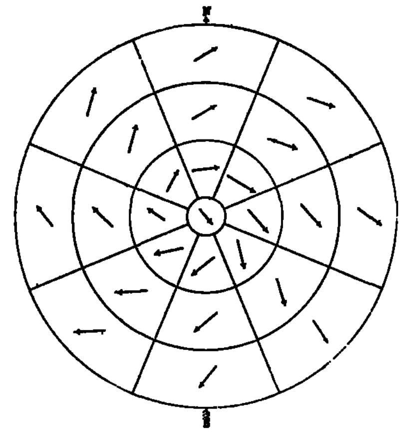

FIG. 10.—Direction of surface winds in anticyclones at Davenport.

less. Observations are lacking in the subareas which have no arrows.

Direction of motion of surface winds.—The resultant direction of the surface wind in each of the subareas of

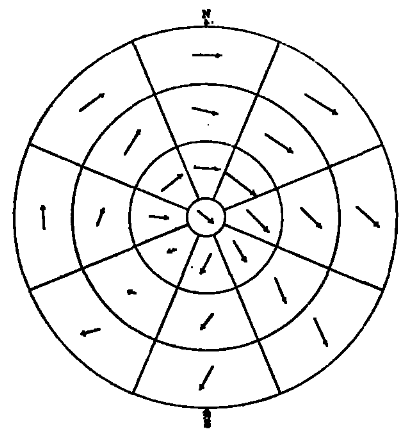

FIG. 11.—Direction of motion of nimbus and stratus clouds in anticyclones at Davenport.

cyclones, overlying Davenport, is shown in Figure 8. The arrows exhibit the characteristic anticlockwise spiral motion of the air in cyclones. Also, the direction

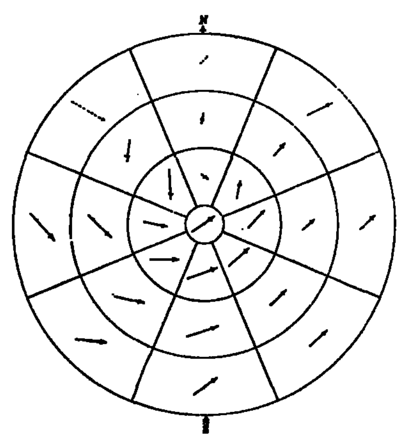

FIG. 12.—Direction of motion of cumulus, strato-cumulus, and cumulo-nimbus clouds in cyclones at Davenport.

of the wind becomes increasingly tangential on approaching the center. The resultant direction of the wind in the central area is from the south, with a slight westerly component.

Direction of motion of nimbus and stratus clouds.—The nimbus and stratus cloud directions shown in Figure 9, likewise possess the spiral motion characteristic of the surface winds. In addition, the winds at this altitude exhibit a westerly trend, noticeable on the eastern side of the cyclonic diagram. In subareas 4, 12, 20 and 5, 13, and 21, for example, the arrows are rotated toward the east from their direction in the surface chart, by almost 45°. The wind direction in the central subareas possesses a greater westerly component than do the surface winds.

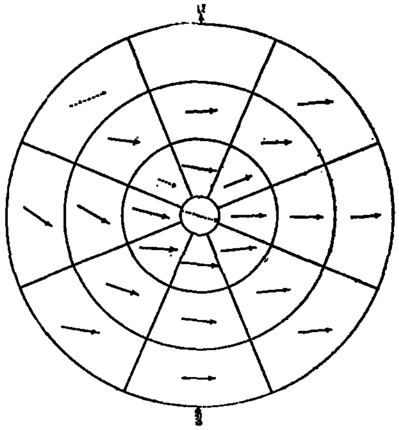

FIG. 13.—Direction of motion of alto-stratus and alto-cumulus clouds in cyclones at Davenport.

Direction of motion of cumulus, strato-cumulus, and cumulo-nimbus clouds.—These appear to represent an intermediate condition between the lowest and the highest winds. The arrows in Figure 12 do not possess the complete spiral arrangement characteristic of the two previous levels. Nevertheless the winds at this altitude clearly show the effect of the cyclonic whirl. The westerly trend of the winds is here very marked in all the areas, including the central one.

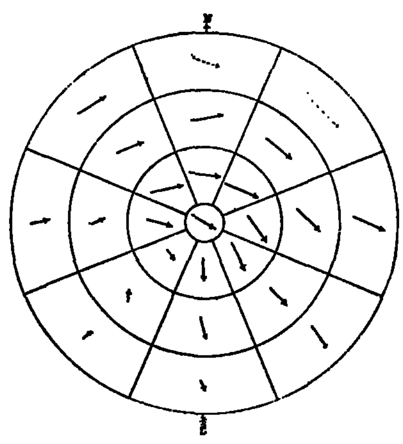

FIG. 14.—Direction of motion of cumulus, strato-cumulus and cumulo-nimbus clouds in anticyclones at Davenport.

Direction of motion of alto-stratus and alto-cumulus clouds.—Except for a slightly southerly convexity in their arrangement, the arrows in Figure 13 do not exhibit any marked effect of the rotary motion of the cyclonic winds. The diagram shows that the alto-stratus and alto-cumulus clouds proceed almost always from a westerly direction regardless of the region of the cyclone in which the clouds occur.

Direction of motion of cirrus, cirro-stratus, and cirro-cumulus clouds.—This is the highest group of clouds. As in the previous case, the arrows exhibit a southward convexity (see fig. 16). The clouds proceed quite regularly from the west in all the areas of the cyclone.

The diagrams, just described, show that the rotary motion of cyclones certainly extends upward to the nimbus and stratus clouds. In most cyclones the rotary motion probably reaches the cumulus group of clouds, and perhaps higher. At this altitude, however, the westerly winds, whose effect is already apparent at the nimbus level, become very marked. At the alto-stratus and cirrus levels the westerly winds proceed almost unhampered by the cyclonic whirl below, whose only effect is to produce a slight southward convexity in the arrangement of the arrows.[3]

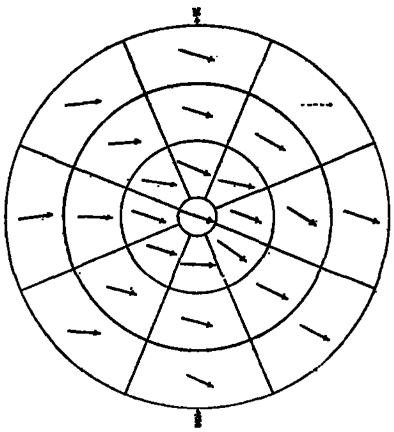

FIG. 15.—Direction of motion of alto-stratus and alto-cumulus clouds in anticyclones at Davenport.

WIND VELOCITIES.

The average wind velocity which Davenport experiences in each of the subareas of the cyclonic diagram is shown in Figure 17. Several variations in velocity are apparent. In the first place the velocity increases radially inward to a maximum at the innermost concentric

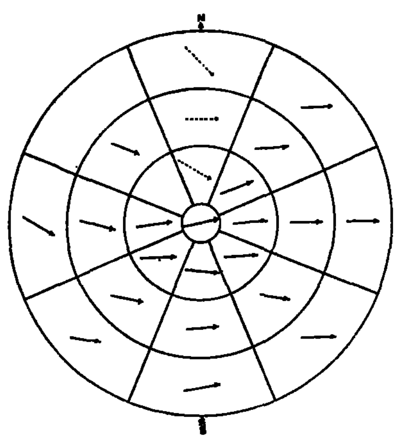

FIG. 16.—Direction of motion of cirrus, cirro-stratus, and cirro-cumulus clouds in cyclones at Davenport.

[3] *The author's conclusion here is reached apparently upon the basis of a sea-level distribution of pressure and upon the assumption that that distribution is reproduced vertically.* It is well known that in most cyclones, especially in winter, the center of lowest pressure at free-air levels is displaced farther and farther toward the colder region with increase of elevation. Thus, the pressure distribution actuating the movement of the higher clouds is not the same as that at the surface or at the level of lower clouds. The conclusion, therefore, that the cyclone does not extend to the cirrus level, based upon the simultaneous observation of surface pressure and the direction of cirrus movement, is hardly tenable.—EDITOR.

ring of subareas, dropping quickly to a value of 7.9 miles per hour in the central area. This is readily seen in Figure 20, in which the velocities are represented on ordinates erected at the centers of subareas lying along four diameters of the cyclonic diagram.

Secondly, the highest wind velocities occur southwest of the central area, where the cyclonic winds below coincide in direction with the prevailing westerly winds above. It would be natural to expect the lowest wind velocities northeast of the central area where the surface cyclonic winds are opposed to the westerly winds above. Instead, comparatively high velocities prevail in this region, with lower wind velocities on either side. The local topography may bring about the condition just described. When Davenport is situated within the regions of highest velocities, the direction of the surface wind is approximately parallel with the valley of the river (compare figs. 8 and 17), so that the valley offers the least possible obstruction to the progress of the wind. On the other hand, when Davenport lies within the adjacent regions of lower velocities, the wind blows across the river valley and its velocity is probably reduced thereby.

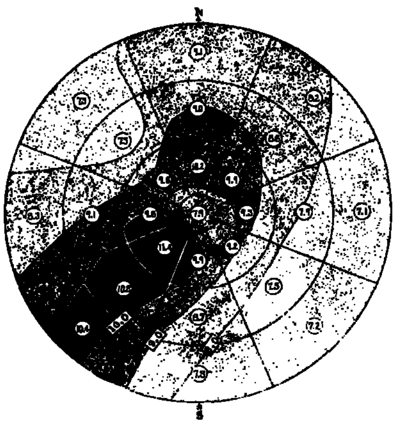

FIG. 17.—Average wind velocities in cyclones at Davenport (miles per hour).

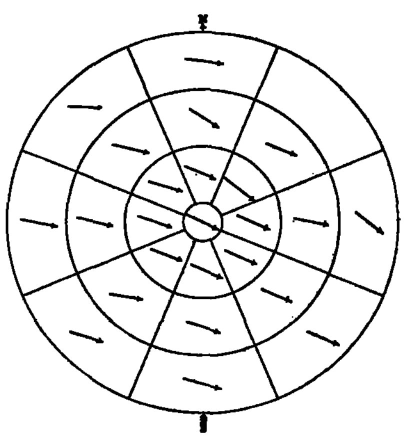

FIG. 18.—Direction of motion of cirrus, cirro-stratus, and cirro-cumulus clouds in anticyclones at Davenport.

PERSISTENCY OF WINDS AND CLOUD MOVEMENTS.

In certain parts or cyclonic areas the wind blows with great regularity from a particular direction, while in other parts the wind direction is extremely variable. This fact is apparent from the following table, which shows the wind directions recorded at Davenport when the city was situated in subareas 1 and 15 of the cyclonic diagram.

	Wind direction.	No. of subarea.	
		1	15
Number of times wind blew from each direction indicated....	N.	7	9
	NE.	9	1
	E.	17	3
	SE.	15	3
	S.	21	7
	SW.	29	96
	W.	14	245
	NW.	7	155
Total number of observations..........................	....	119	519

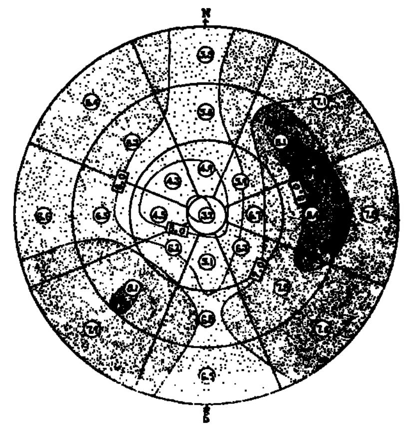

FIG. 19—Average wind velocities in anticyclones at Davenport (miles per hour).

When Davenport lay in area 15 the wind blew almost always from the southwest, west or northwest, 496 out of 519 times. On the other hand when the city lay in the central cyclonic area, No. 1, the wind was extremely variable in direction.

It appears desirable to obtain a numerical measure of the regularity or "persistency" with which the wind tends to blow in a particular direction. Expressed in per cent, a persistency of 100 per cent would mean that the wind blew every time from the same direction. Zero persistency implies that the wind direction is so variable that there is no resultant direction. A numerical measure of the persistency of direction may therefore be obtained by expressing in per cent the ratio of the length of the resultant direction (from a graphical plot) of the total number of observations. As an illustration to the method, the persistency of wind direction in subarea 15 of the cyclonic diagram is given below.

$$\text{Persistency} = \frac{\text{Length of resultant from graph } 418}{\text{Total number of observations } 519} \times 100 = 81 \text{ per cent.}$$

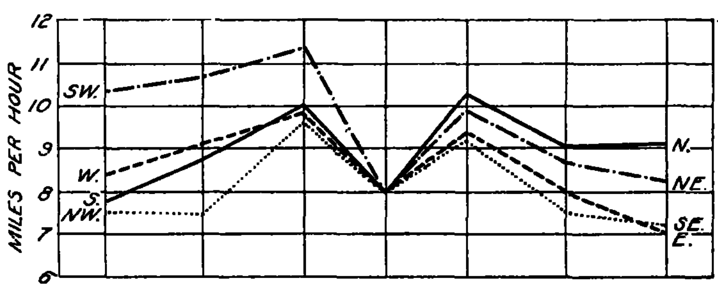

FIG. 20.—Radial variation in wind velocities in a cyclone at Davenport. The figures at the side give the velocities in miles per hour. The vertical line in the center is erected on the center of the cyclone. The two lines next outside rise from the centers of subareas 2 to 5 and 6 to 9, respectively; the next outer lines from subareas 10 to 13, and 14 to 17, etc. See fig. 1 for location of subareas.

In the wind direction diagrams 8, 12, 13, and 16, the lengths of the arrows were made proportional to the persistency of the wind direction in each subarea.

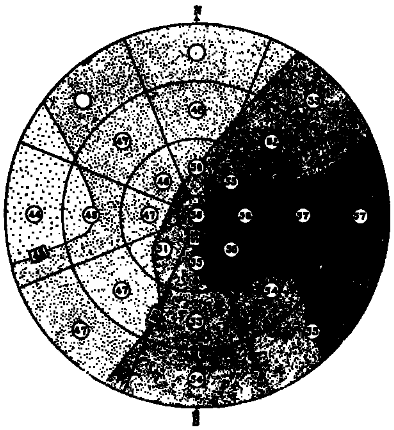

FIG. 21.—Distribution of temperature in cyclones at Davenport (°F.).

Irregular topographic features probably affect the surface wind persistencies. In the main, however, the

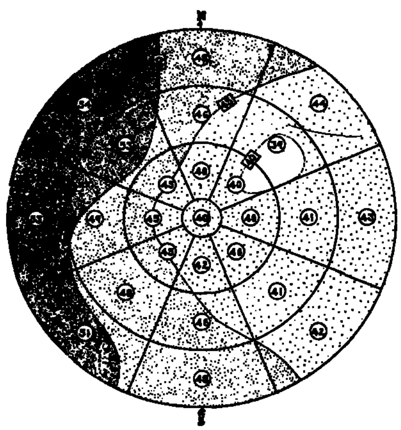

FIG. 22.—Distribution of temperature in anticyclones at Davenport (°F.).

surface persistency values are determined by the cyclonic motion of the wind. This gives rise to a region of high

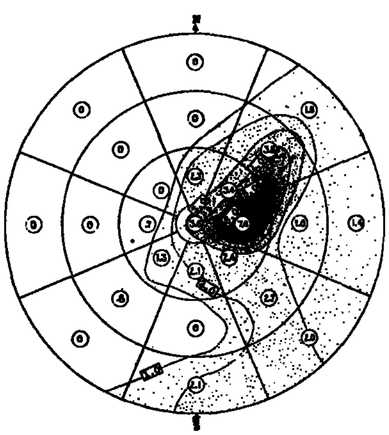

FIG. 23.—Frequency of thunderstorms in cyclones at Davenport. Numbers in subareas represent the number of thunderstorms per 100 times that Davenport falls within a given subarea.

persistency values southwest of the center and lower persistencies to the northeast. At the height of the nimbus, stratus and cumulus groups of clouds these two regions of high and low persistency are sharply defined, clearly indicating that the cyclonic motion extends to this height. High persistency values prevail in all areas at the alto and the cirrus levels, due to the prevailing westerly winds.

RESULTANT VECTORS AND WESTERLY COMPONENTS OF ALL WIND MOVEMENTS AT FIVE DIFFERENT LEVELS.

Finally we may combine the 25 resultant wind directions at a given level into a single total resultant direction for that altitude. In this way five total resultant wind directions have been obtained, one for each level.

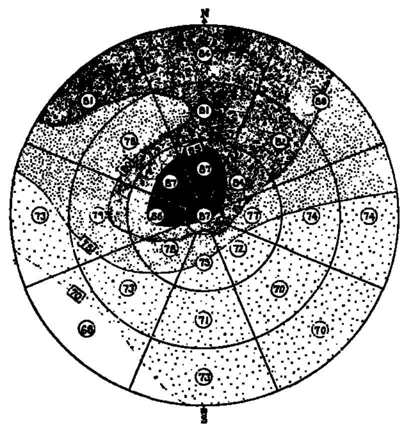

FIG. 24.—Average distribution of relative humidity in cyclones at Davenport.

These resultant wind directions are indicated by the broken lines in Figure 46. The full lines in this figure represent the westerly components of the resultant directions at the respective levels. The approximate altitudes of the respective wind levels is given along

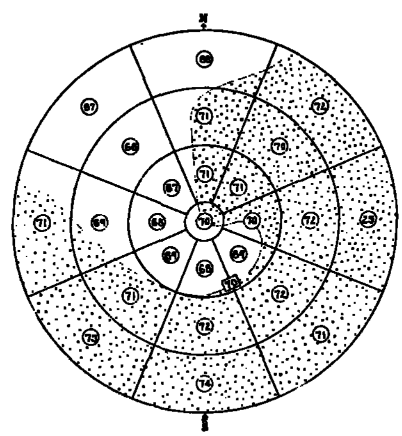

FIG. 25.—Average distribution of relative humidity in anticyclones at Davenport.

the ordinate, while the persistency of the westerly components is measured along the abscissa. This is as below.

	Westerly component persistency in per cent.
1. Surface wind	5.0
2. Nimbus and stratus	19.4
3. Cumulus, strato-cumulus and cumulo-nimbus	45.7
4. Alto-stratus and alto-cumulus	82.4
5. Cirrus, cirro-stratus and cirro-cumulus	82.5

It is seen that the 25 surface winds of the cyclonic diagram, when combined into a single vector, possess a slight westerly component. This component is small because at the surface the cyclonic motion of the winds is most pronounced. With increase in altitude the cyclonic motion decreases and the westerly winds increase in strength. The curved line in Figure 46 shows graphically this increase in the total resultant westerly component of the wind direction as the altitude increases.

TEMPERATURE.

The average temperature which Davenport experiences in each of the cyclonic subareas is shown in Figure

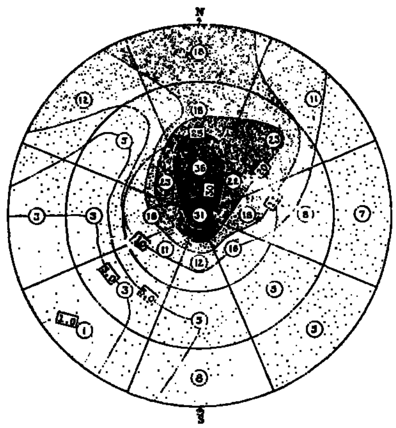

FIG. 26.—Percentage frequency of rainfall in the different subareas of cyclones at Davenport.

21. The temperatures represent the arithmetical average based on the total number of observations, morning and evening, for the respective subareas. The distribution of temperatures is such as we might expect within a cyclone. The higher temperatures occur on the eastern side where the winds are from the south and the lower temperatures on the western side where the winds are from the north.

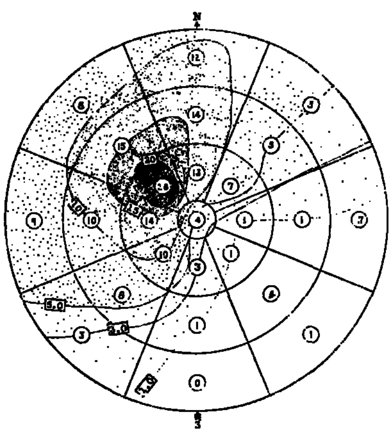

FIG. 27.—Percentage frequency of snowfall in the different subareas of cyclones at Davenport.

FREQUENCY OF THUNDERSTORMS.

The percentage frequency of thunderstorms in the various parts of cyclonic areas is given in Figure 23. There are on the average 3.6 thunderstorms for every 100 times that Davenport falls within the central region. This result, like all others in this paper, is based on the morning and evening observations throughout the entire period under consideration. The percentage frequency of thunderstorms would no doubt be greater for the summer season and less for the winter months.

The diagram shows that thunderstorms frequently occur on the eastern side of LOWS and are almost lacking on the western side. Thunderstorms are most frequent when Davenport lies in a region about 100 to 300 miles east of the center of the LOW.

RELATIVE HUMIDITY.

Figure 24 gives the average relative humidity for each of the subareas of the cyclonic diagram. The lowest values of relative humidity occur in southern subareas while high values prevail in the northern half of the

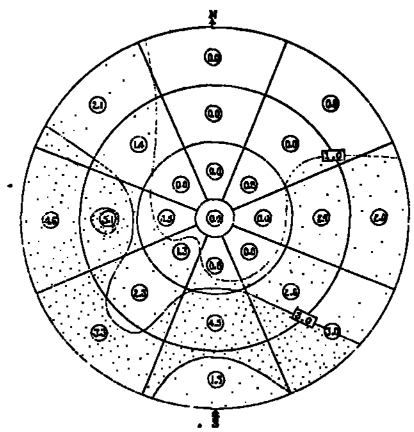

FIG. 28.—Percentage frequency of rainfall in the different subareas of anticyclones at Davenport.

cyclonic diagram. The maximum relative humidity occurs when Davenport lies within a small region just northwest of the center of the diagram.

FREQUENCY OF RAINFALL.

This frequency of rainfall in the various subareas of the cyclonic diagram is shown in Figure 26. The frequency

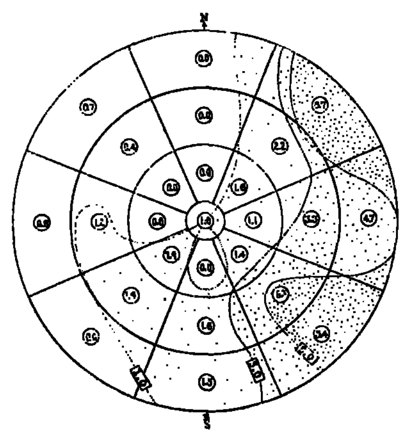

FIG. 29.—Percentage frequency of snowfall in the different subareas of anticyclones at Davenport.

of rainfall is highest in northern subareas, and, in particular, rainfall is most frequent at Davenport when the city lies within a region extending from 300 miles northward from the center of the cyclonic diagram. In subarea 2 where the frequency is greatest, it rains on the average 36 out of 100 times. The frequency of rainfall is least in the southern subareas, the minimum frequency occurring in 23, southwest of the center.

FREQUENCY OF SNOWFALL.

This is pictured in Figure 27. Snowfall rarely occurs southeast of the center of the cyclonic diagram, where the winds are from the south. The frequency of snowfall is high in the northwestern subareas, where the winds

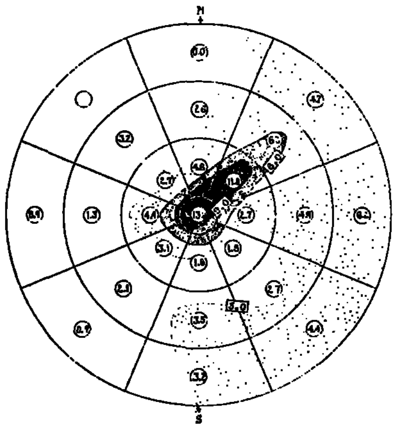

FIG. 30.—Percentage frequency of fogs in cyclones at Davenport.

are from the north. The maximum frequency occurs when Davenport is situated in a small region just northwest of the center of the LOW.

The region of maximum relative humidity coincides approximately with the regions of greatest frequency of rainfall and snowfall. If the latter two diagrams were combined into one this coincidence would be all the more apparent.

Textbooks frequently refer to the region southeast of the center of the cyclone as the rain-bearing area. This may be true for certain parts of the United States and perhaps for other countries. For Davenport, however, it seems certain that the principal rainfall region lies north of the center of a LOW. This may be due in a large measure to the presence of the Great Lakes and other bodies of water north and east of Davenport. Winds blowing over these regions have a chance to become moisture laden before reaching Davenport. On the other

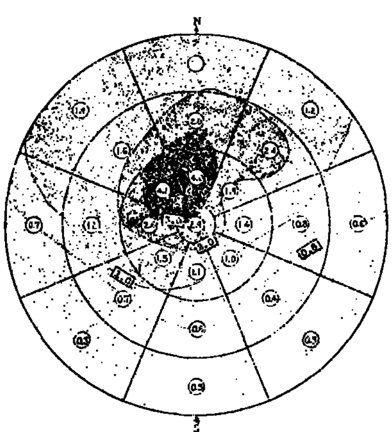

FIG. 31.—Percentage frequency of nimbus clouds in cyclones at Davenport.

hand winds coming from the south and west do not traverse any large water surfaces and this may in part account for the low rainfall frequency south and west of the center of the cyclonic diagram.[4]

FREQUENCY OF FOGS.

Fogs are decidedly more frequent when Davenport is situated on the eastern side of a LOW than on the western side. This is clearly seen in Figure 30. Maximum frequency occurs at the center of the cyclonic diagram in a region which extends several hundred miles to the northeast. In the central region fogs occur 13 out of every 100 times that Davenport lies in this area.

It has been frequently noticed that light fogs on the uplands around Davenport may become very dense upon descending a short distance into the valley below. The occurrence of fogs in this locality is no doubt closely related to the presence of the river. Light winds blowing parallel with the direction of the river would probably favor the formation of fogs. In subareas 3 and 11 where the frequency is high, the direction of the wind is approximately parallel with the direction of the river valley.

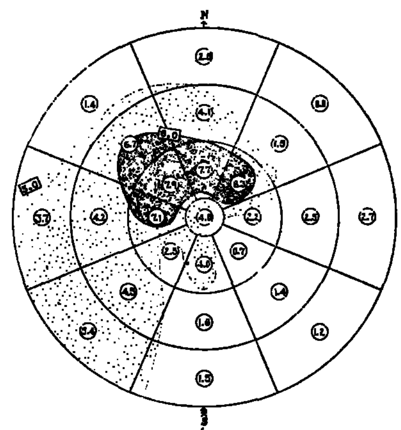

FIG 32.—Percentage frequency of fogs in anticyclones at Davenport.

DISTRIBUTION OF CLOUDINESS IN CYCLONES AT DAVENPORT.

The following types of clouds have been studied with reference to their distribution in the cyclonic diagram:

1. Nimbus
2. Stratus.
3. Cumulus.
4. Alto-cumulus.
5. Alto-stratus.
6. Cirro-stratus.
7. Cirrus.

On account of the small number of observations the other cloud forms were omitted. Following the usual practice, the amount of cloudiness has been designated by the scale of 1 to 10, where 10 represents total cloudiness, when the sky is overcast.

Nimbus cloudiness.—The amount of nimbus cloudiness is least in the southern areas of the cyclonic diagram and increases toward the north (fig. 31). The region of maximum nimbus cloudiness occurs north and slightly west of the center of the cyclonic diagram. This diagram should be compared with figures 24, 26, and 27. Naturally the region of greatest nimbus cloudiness coincides with the regions of maximum relative humidity, rainfall, and snowfall frequency.

[4] The distribution here shown conforms closely with that of Bjerknes's typical cyclone (cf. MO. WEATHER REV., February, 1919, 47: 95–99) and therefore local conditions seem to play but a minor rôle.—EDITOR.

Stratus cloudiness.—The distribution of the stratus clouds (fig. 34) is quite similar to that of the nimbus clouds. The region of maximum stratus cloudiness, however, broadens out toward the north. Also, the average amount of stratus cloudiness is greater than for the nimbus clouds.

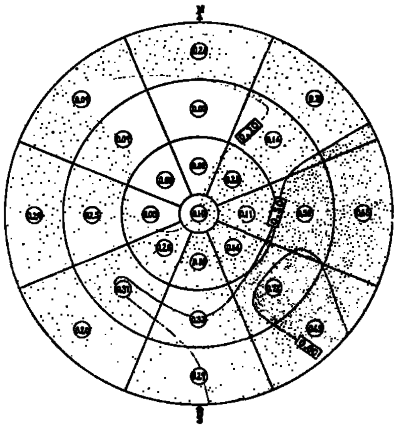

FIG. 33.—Percentage frequency of nimbus clouds in anticyclones at Davenport.

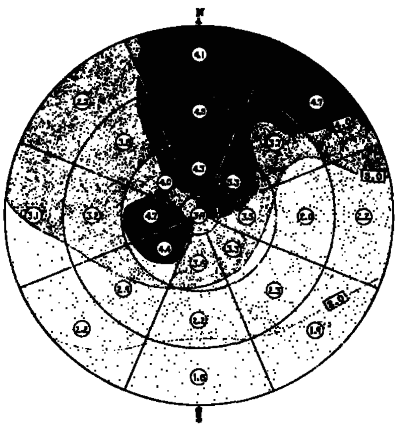

FIG. 34.—Percentage frequency of stratus clouds in cyclones at Davenport.

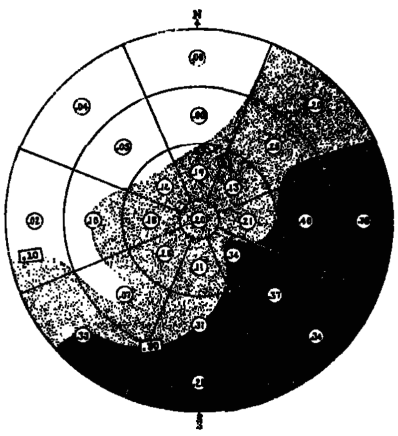

FIG. 35.—Percentage frequency of cumulus clouds in cyclones at Davenport.

Cumulus cloudiness.—The cumulus clouds occur mainly southeast and east of the center of the LOW, as shown in figure 35. This was to be expected inasmuch as convection is very pronounced in this part of the cyclone.

Alto-cumulus.—The distribution of alto-cumulus clouds in the cyclonic diagram is shown in Figure 38. On account of the small number of observations for the higher clouds, this and the remaining cyclonic diagrams present many irregularities in their appearance. Only the more general features of the diagrams are therefore considered significant. The alto-cumulus clouds are most common on the eastern side of the cyclone. The average amount of this kind of clouds is seen to be very small.

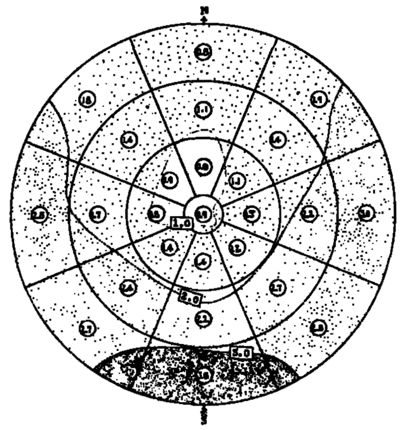

FIG. 36.—Percentage frequency of stratus clouds in anticyclones at Davenport.

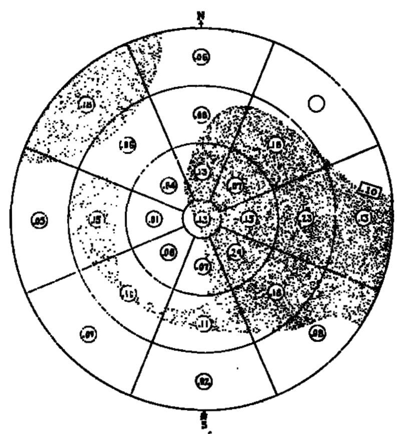

FIG. 37.—Percentage frequency of cumulus clouds in anticyclones at Davenport.

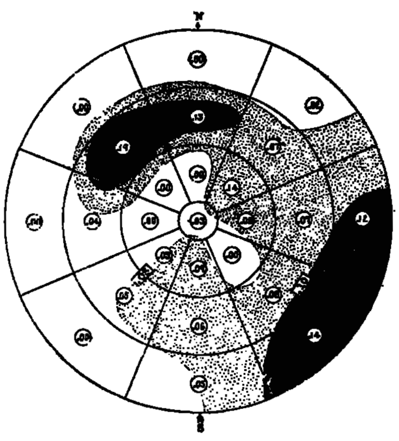

FIG. 38.—Percentage frequency of alto-cumulus clouds in cyclones at Davenport.

Alto-stratus cloudiness.—The alto-stratus clouds (fig. 39) likewise are present chiefly on the eastern side of the cyclonic diagram. These clouds are present in fairly high frequency, the highest average value of the cloudiness being approximately equal to 1.

Cirro-stratus cloudiness.—The cirro-stratus clouds also occur mainly on the eastern side of the low. The average cirro-stratus cloudiness is slightly less than the alto-stratus. (See fig. 42.)

Cirrus cloudiness.—The amount of cirrus clouds is very small and the clouds are most prevalent in the eastern subareas of the cyclonic diagram. (See fig. 43.)

With regard to their distribution in the cyclonic diagram the clouds here described may be divided into three large groups.

1. The approximately similar distribution of nimbus and stratus cloudiness is closely related to the distribution of precipitation and relative humidity at the surface.

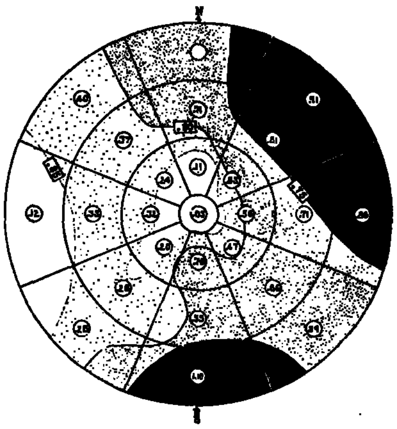

FIG. 39.—Percentage frequency of alto-stratus clouds in cyclones at Davenport.

2. The cumulus cloud distribution toward the southeast is such as to favor the accepted theory of their convectional origin.

3. The alto-cumulus, alto-stratus, cirro-stratus and cirrus clouds occur at high altitudes. In all cases under this third group the amount of cloudiness is greatest in the eastern and least on the western side of the cyclonic diagram.

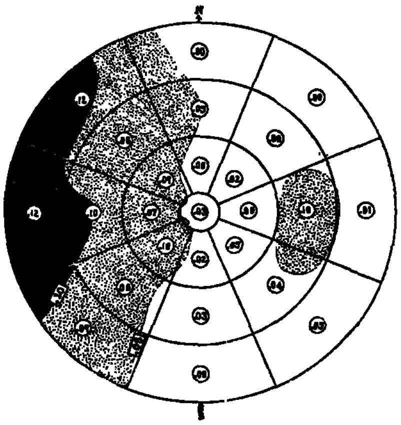

FIG. 40.—Percentage frequency of alto-cumulus clouds in anticyclones at Davenport.

SURFACE AND UPPER AIR CONDITIONS IN ANTICYCLONIC SUBAREAS OVERLYING DAVENPORT, IOWA.

The average weather conditions at Davenport, when situated in particular regions of anticyclones, have been studied in the same manner as for cyclones. The results of this study will be briefly presented in the following paragraphs, together with a comparison of the weather conditions in some regions of the cyclonic diagram. The same diagram of 25 subareas was used for studying both the HIGHS and LOWS.

NUMBER OF OBSERVATIONS IN DIFFERENT SUBAREAS OF ANTICYCLONES.

A comparison of Figure 5 and Figure 3 show that the distribution of the number of observations in the anticyclonic diagram is in one respect similar to the distribution in the cyclonic diagram. In each instance there is a crescent-shaped area below the center of the diagram

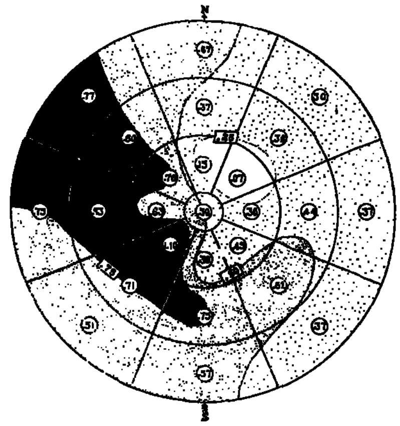

FIG. 41.—Percentage frequency of alto-stratus clouds in anticyclones at Davenport.

containing two maxima of observations. The total number of observations in the different parts of anticyclones, namely, 5,286, is 986 more than in the cyclonic diagram. The observations in the anticyclonic diagram are somewhat more evenly distributed among all the different areas of the anticyclone than are the observations in the cyclones.

Frequency of observations.—This has previously been defined as the number of observations per unit of area in each subdivision. It will also be remembered that the frequency values depend upon the directions of the paths traversed by anticyclones in passing over Davenport in such a way that the frequency areas become elongated in a direction parallel to the paths of the HIGHS. The frequency areas in Figure 6 are elongated from east to

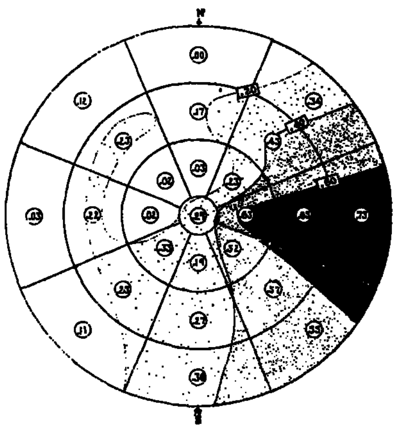

FIG. 42.—Percentage frequency of cirro-stratus clouds in cyclones at Davenport.

west with a slight dip toward the southeast. This is the prevailing direction of the paths of anticyclones at Davenport. Finally, the figure also shows that anticyclones pass with almost equal frequency north and south of Davenport.

DIRECTION OF THE SURFACE WINDS AND THE CURRENTS IN THE UPPER AIR IN ANTICYCLONES.

Surface winds.—The resultant direction of the surface wind at Davenport when the city is situated in the various subareas of the anticyclonic diagram is shown in Figure 10. The arrows exhibit the usual clockwise

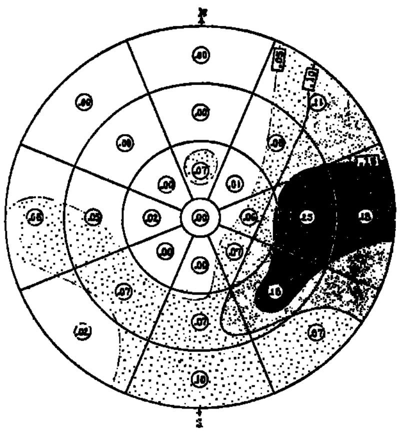

FIG. 43.—Percentage frequency of cirrus clouds in cyclones at Davenport.

arrangement characteristic of anticyclonic winds. In the central region the resultant wind direction is northwest.

Direction of motion of nimbus and stratus clouds.—Compared with Figure 10 it will be seen that many of the arrows in Figure 11 have been rotated toward the east, especially in the northwest of the diagram, clearly showing the effect of the prevailing westerly winds at this altitude. Nevertheless, the regular clockwise arrangement of the arrows indicates that the anticlockwise motion is predominant at the height of the nimbus and stratus clouds.

Direction of motion of cumulus, strato-cumulus and cumulo-nimbus clouds.—The anticyclonic motion of the air, although very evident at this height, appears to be breaking up. (See fig. 14.) The effect of the westerly

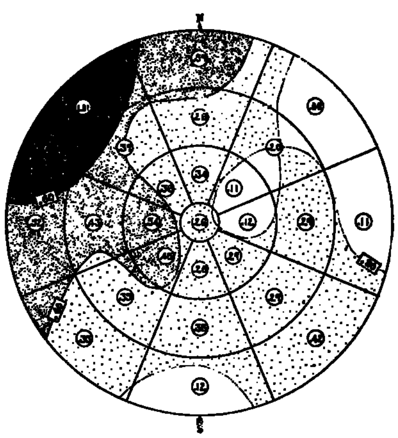

FIG. 44.—Percentage frequency of cirro-stratus clouds in anticyclones at Davenport.

winds is more noticeable than in the previous figure. The diagram suggests a transitional stage between the anticyclonic motion below and the westerly winds above.

In the central region the resultant wind direction is from the northwest, becoming more westerly at the higher altitudes. Comparing this with the cyclonic diagram, it is seen that the wind direction in the central region of the cyclone is now from the southwest and becomes more westerly with increasing altitude.

Wind velocity.—The average wind velocity which Davenport experiences in each of the subdivisions of the anticyclone is shown in Figure 19. The radial variation in velocity is very apparent from Figure 47. Naturally the velocity is least in the central region. Steep pressure gradients usually occur in front of winter anticyclones, and this is probably the cause of the region of high velocity in the eastern parts of the cyclonic diagram.

The average wind velocities throughout the anticyclonic diagram are considerably less than in the cyclonic diagram. This is especially noticeable at the center of the anticyclone where the average velocity is 3.7 miles per hour as compared with a velocity of 7.9 miles per hour in the same area in the cyclonic diagram.

Direction of motion of alto-stratus and alto-cumulus clouds.—The average motion of these clouds is distinctly from the west. The only trace of the cyclonic whirl below is the upward convex arrangement of the arrows (fig. 15).

Direction of motion of cirrus, cirro-stratus, and cirro-cumulus clouds.—All the arrows in this diagram are practically parallel. The convex arrangement, characteristic of the previous level, has almost disappeared.

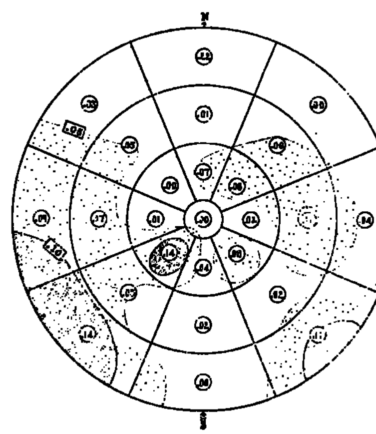

FIG. 45.—Percentage frequency of cirrus clouds in anticyclones at Davenport.

It is interesting to note that while the cirrus clouds in the cyclonic diagram are almost directly from the west, in the anticyclone all the arrows possess a definite northerly component in addition to the westerly direction (fig. 18).

At the surface and nimbus-stratus levels the air motion is anticyclonic. The cumulus group of clouds are neither clearly anticyclonic nor westerly in their motion. At the alto and cirrus levels the motion of the air is distinctly to the east.

RESULTANT VECTORS OF ALL WIND MOVEMENTS AT FIVE DIFFERENT LEVELS.

The total resultant wind direction and persistency for Davenport at each of the five levels is shown by the broken arrows in Figure 48. With increasing altitude the total resultant wind directions become more westerly. The westerly components of the resultant directions are shown by the heavy lines, and the persistency of these components is given below.

Surface wind	9.0
Nimbus-stratus	29.7
Cumulus group	48.4
Alto group	78.0
Cirrus group	79.7

The curved line in Figure 48 shows graphically the increase in the westerly component of the total resultant directions for the respective levels.

Figures 46 and 48 are quite similar. In both diagrams the westerly components reach a maximum at about the elevation of the alto-stratus and alto-cumulus group of clouds. The diagrams suggest that the principal effect of the rotary motion of cyclones and anticyclones extend on the average to about this height.

TEMPERATURE.

The average temperature for Davenport in each of the anticyclonic subdivisions is given in Figure 22. The highest temperature values occur west of the center of the diagram where the winds are from the south while the lowest occur east of the center where the winds are from the north.

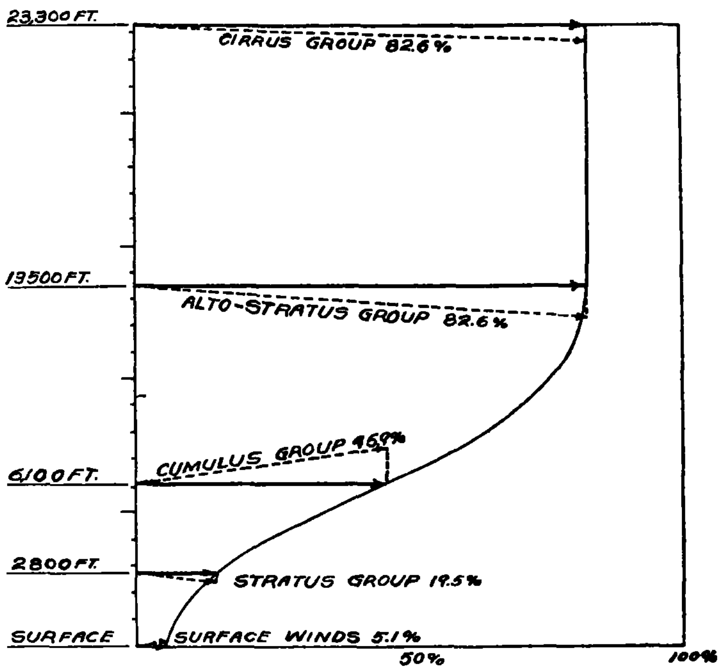

FIG. 46.—Resultant vectors and westerly component of all winds and cloud movements at each of five different levels in a cyclone at Davenport.

FREQUENCY OF THUNDERSTORMS.

Thunderstorms are naturally quite rare in anticyclones. When they do occur it is mainly in western regions where the temperatures are highest. The greatest frequency recorded is subarea 23, where thunderstorms occur, on the average, 1.1 out of every 100 times that Davenport lies within that subarea. Thunderstorms are almost lacking on the western side of the cyclone and on the eastern side of the anticyclone where the winds are from the north.

RELATIVE HUMIDITY.

Figure 41 gives the average relative humidity for Davenport in each part of the anticyclonic diagram. The relative humidity is seen to be greatest when Davenport is situated in the southern and the eastern part of the diagram, respectively, and least in the northern part. In the cyclonic diagram almost the reverse is true. The relative humidity is there least in the southern and greatest in the northern part.

FREQUENCY OF RAINFALL.

The frequency of rainfall at Davenport, when the city is situated in an anticyclone, is greatest in the southern part of the diagram and least in the northern (fig. 28). The frequency values are quite low, the highest being 5.1 rainfall occurrences per 100 observations in subarea 16.

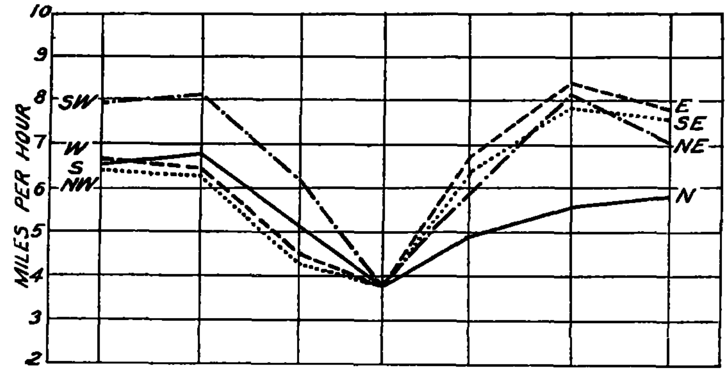

FIG. 47.—Radial variation in wind velocities in an anticyclone at Davenport. For explanation of the construction of the figure see fig. 20.

FREQUENCY OF SNOWFALL.

In the anticyclonic diagram the greatest frequency of snowfall (fig. 29) occurs when Davenport lies in the subareas southeast of the center of the diagram where the winds are from the north. The least frequency of snowfall is found in the subareas northwest of the center of the diagram where the winds are from the south. The high frequencies southeast of the center of the anticyclonic diagram match the high frequencies northwest of the center of the cyclonic diagram. In both these cases the winds have the same general direction.

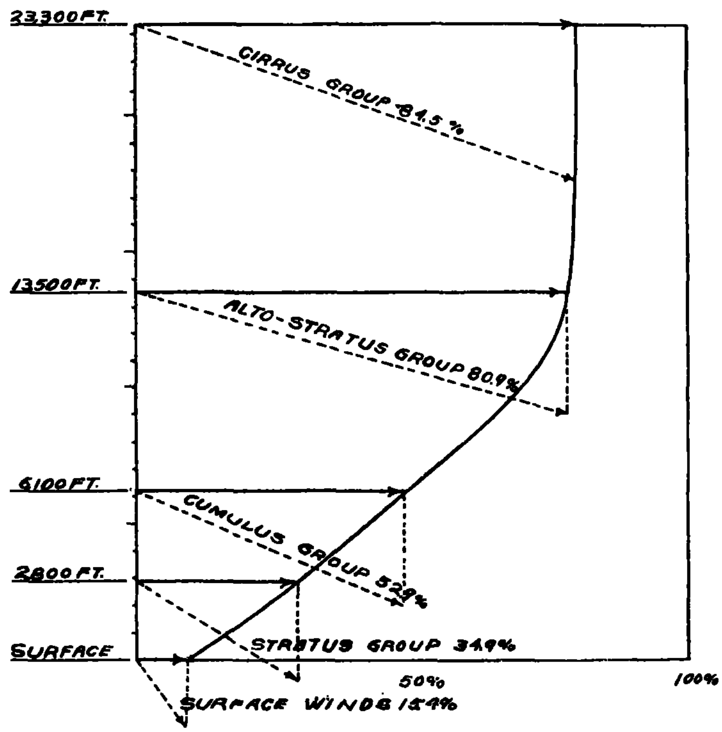

FIG. 48.—Resultant vectors and westerly component of all winds and cloud movements at each of five different levels in an anticyclone at Davenport.

FREQUENCY OF FOGS.

In the anticyclones, as in the cyclones, the distribution of the frequency of fogs for Davenport seems rather erratic. On the whole, fogs are least frequent in the east half of the anticyclone where the winds are from the north (fig. 32). The area of greatest frequency lies in subareas 2, 3, 8, 9, and 17. It is quite likely that the presence of the Mississippi River affects, to some extent, the frequency of fogs in anticyclones.

FREQUENCY OF CLOUDINESS.

The total number of observations on clouds in anticyclones is, of course, much smaller than the number of observations on clouds in cyclones. As a result of this the figures showing cloudiness in the anticyclones present many irregularities. This is especially true with regard to the higher clouds. The distribution of cloudiness in the anticyclones is clearly the reverse of the distribution of cloudiness in cyclones in the case of the nimbus (fig. 33), the stratus (fig. 36), the alto-stratus (fig. 41), and the cirro-stratus (fig. 44) clouds. This condition is less evident in case of the alto-cumulus (fig. 40) and the cirrus (fig. 45) clouds, and it can not be said to be at all noticeable in the chart for the cumulus clouds (fig. 37). Averages based on a larger number of observations must be expected to change some of these charts.

CONCLUSION.

In this paper, the author has limited himself mostly to statements of facts supplementary to the illustrations. This was done in the belief that a fuller discussion of the elements of the weather, in any single locality, can best be made after other studies, like these, shall have been worked out for other places, representing several climatic regions in our country. Such studies would enable us to make comparisons from which we could infer, with greater confidence than we can do now, the causes of distribution of weather elements. With the wealth of material at hand for such studies, there can hardly be any doubt but that tabulations like those presented here will sooner or later be made on a basis that will render such comparative studies productive of important results.

BRAZILIAN METEOROLOGICAL SERVICE (1921-1923.)

By J. DE SAMPAIO FERRAZ, Director.

[Directoria de Meteorologia, Rio de Janeiro, February 16, 1923.]

Deeming it of some interest to other meteorological organizations of the world, we have prepared for their benefit a short resumé of the work done in the last 20 months by the new Brazilian Meteorological Service, created in June, 1921. As explained in our Foreign Circular No. 1 of that year, the meteorological activities in Brazil always depended on other bureaus, and before 1921 it was often simply a department of astronomical organizations. While the program was limited to pure climatological work, there was not much harm done in this partnership. But with the development of the net of stations and the possibility of their being utilized in other departments of general meteorology, and moreover with the progress of atmospheric science, rapidly creating new services, the old arrangement was certainly an inconvenience. To make this evident we have indicated in this report the good results brought about by the independence of the meteorological service in Brazil. The contrast will be clearer if we first show what the old service was doing in May, 1921, just before the establishment of the present directoria. Despite the direction of my distinguished predecessor, Dr. Henrique Morize, whose first attempts to classify and investigate Brazilian climatology are well known, the old directoria confined itself strictly to the climatological work. Weather forecasting was under our personal supervision, studied and practiced *intra muros*, with distribution restricted to the capital. The net of stations was greatly augmented by the old organization, but no publications were issued except for the year 1910, which we had printed in Brussels together with our *Instrucções Meteorologicas*.

Now, let us point out what the new independent service has done in the last 20 months and is doing at present.

Climatology.—The old service had in May, 1921, 51 stations of second order, 46 of third order, 31 pluviometric, and 26 cooperative. The new bureau has now 74 stations of second order, 78 of third order, 57 pluviometric, and 180 cooperative. Inspection, which was previously almost nonexistant, is now actively carried out all over the country. Yearly bulletins were put out for 1911, 1912, 1913, 1914, 1915, 1916, 1917, 1918, and a book of normals was issued; 1919 and 1920 are being printed. Before June, 1921, no data were published in newspapers. Now every station is obliged to publish two-weekly reports, and those that are located in capitals of States issue daily summaries of their weather and that of other points of interest to the local population and business.

Weather forecasting.—The new service started distribution of daily forecasts through the southern States, using telegraph and telephone. Forecasting with synoptic charts is only possible in the southern States of Brazil. The service was organized in Rio de Janeiro and São Paulo where every farmer near a railway station, a telephone or a telegraphic office, can receive before 6 o'clock in the evening the official forecasts for the next 24 hours. Santa Catharina and Parana are being prepared to have the same service this year. In the large towns the weather forecasts are distributed by flags.

Several storm warning towers were put up on the southern coast. All the radio stations of the coast, 12 in number, broadcast every 4 hours the weather of the occasion, the wind direction and speed being given by automatically recording instruments. Rio's radio station gives out special bulletins with data of chosen points and the forecasts for weather of night and day. Forecasts are also sent out by radio telephone from Corcovado (Rio).

The Brazilian isobaric charts are constructed from reports of 80 Brazilian stations (from Bahia to Rio Grande), 18 Argentine stations and 6 from Uruguay. On account of the very variable topography of the country and its extensive high plateaus, winds and pressures can only be rightly interpreted with long experience, and in many cases are very troublesome to the forecasters. New processes based on these elements can not be followed in Brazil. Our own empirical rules had